ART. XIV.—*On the Structure and Growth of the Tissues, and on Life.* Ten Lectures delivered at King's College, London. By LIONEL S. BEALE, M. B., F. R. S., Physician to King's College Hospital, Professor of Physiology and of General Morbid Anatomy in King's College, London, &c. 12mo. pp. 219. London: Robert Hardwicke, 1865.

THE cellular composition of tissues, and the cellular theory of their development and growth, in one or other of its accepted forms, have been so long admitted by physiologists, while the more recent interpretation of this theory, and its application to pathological structures by Virchow have been received with such universal favour, that any theory which militates against it cannot but startle those who have settled into its acceptance, and must have a stable foundation to be permitted to displace it.

Founded, as is the theory of Beale, upon his own personal observations—observations which carry on their face the impress of truth and reliability, it has seemed to us that his ideas have not attracted that attention from American physiologists which they deserve. Having trained himself to most accurate execution with the pencil, Dr. Beale makes all his own drawings, and no one who has examined the cuts in any of his carefully prepared works, as those accompanying the lectures on the tissues as first published in the *Archives of Medicine*, those in either of his valuable books *How to Work the Microscope*, and *The Microscope in Clinical Medicine*, or the illustrations to his more recent labours on the direction of nerve currents and distribution of ultimate nerve fibres to muscular fasciculi, can fail to be convinced of the skill and accuracy with which his drawings are made. Nor are we compelled to rely upon our comparison of the labours with our own ideas of what they should be, for we have been informed by a medical friend who has recently had the advantages of Dr. Beale's teachings, and who saw the original microscopic appearances, that the drawings represent them most truthfully.

If there be error, then, in the theory of Beale, which we do not deny (our object being merely to make its principal points more accessible to American medical men), it must be in the train of reasoning rather than in the premises, which appear to be true.

That the theories of Beale and Virchow are opposed to each other, in a greater or less degree, is plain; but the exact nature and degree of difference we fear is not appreciated by many of our countrymen. And it shall be our aim, in the following review, to indicate, as far as possible, the points and degree of difference.

Dr. B.'s first lecture contains an enumerative review of the organic functions with brief definitions, and a slightly more extended consideration of the nature of the process of *nutrition, i. e.*, "the manner in which the soluble material, which is brought into relation with a living tissue, is taken up by that tissue and incorporated with it; how it becomes converted from an inanimate into a living substance; how the whole organism grows; how tissues increase in size until the adult form is attained; how the waste resulting from action is supplied by the production of new tissues." The difficulty of answering such questions as these is admitted, and in many cases the impossibility of conclusive answer. "But by reasoning upon facts obtained by experiment, and upon the observations derived from very minute examination of the tissues with the highest powers of the microscope, inferences which in many instances probably approximate the truth, have been obtained." The importance of a consideration of the theories advanced for the explanation of these phenomena is manifest from the fact that of late these matters have been discussed, not only in scientific books, but even in the current literature of the day. Hence medical men are at any time liable to be called upon to give an opinion regarding various points connected therewith. An additional reason for the study of these theories lies in the fact that it is impossible to know anything of the action of the body in health without investigating the minute changes which go on in the organism. "This knowledge forms the foundation of physiological science, and from this point of view the changes taking place in disease can alone be studied with any advantage. It is the natural introduction to the study of medicine." Still another reason adduced by Dr. Beale for the earnest study and advancement of every branch of science bearing upon medicine is the influence which increased knowledge must exert in exposing the false character of the many plausible arguments which are brought forward in favour of various forms of quackery. His remarks are so eminently applicable to the circumstances by which we are now surrounded in our own and every American community, and involve so entirely the only remedy for their removal, that a quotation of the entire paragraph is justified, though somewhat irrelevant to the strict purpose of the lecture.

> "It is quite clear that if the principles upon which we act were as capable of proof as many of the general doctrines of chemistry, quack dogmas would very soon be exposed; but charlatans know well that the arguments from which our principles of action are deduced cannot be understood by any one ignorant of physical science, while by putting forward false premises, and drawing from these a logical conclusion, they very easily convince even an intelligent, well educated man, who is unable or disinclined to analyze their premises, that there is some reason in their statements. Depend upon it, gentlemen, the only efficient way of opposing the spread of quackery among the public is to encourage the spread of scientific investigation and a love for research among ourselves, and by this course alone shall we be able to shame those amongst us who are base enough to their profession to support and pamper an impostor or encourage a stupid system of treatment because they have not the courage to offend the prejudices, or oppose the caprices of some self-willed, wealthy, and, perhaps, influential person. We must oppose the spread of quackery, and endeavour to prevent the harm resulting from it, by increased devotion to our profession, by prosecuting researches for the discovery of new truths, or for confirming facts which appear inconclusive, and by unremitting efforts to demonstrate simply and most conclusively the soundness of the fundamental principles of medicine. The skill of the modern chemist exposes the vicious refinements of the most ingenious and subtle poisoner; and in the same way our earnestness and gradually increasing knowledge of disease must ultimately destroy the influence which unscrupulous charlatans have long exerted upon ignorant persons." (pp. 6–7.)

Next follows a brief exposition of "the cell and other theories," premised by the admitted proposition, "*all living structures spring from pre-existing living structures.*" Again, all living structures are perpetually undergoing change; they grow, are nourished, exist for a time, and ultimately die. They possess the power of assimilating to themselves lifeless matter, and communicating to it the same peculiar properties with which they themselves are endowed; and, further, they possess the power of multiplying themselves infinitely, of giving rise to other organisms which inherit similar properties to those which their progenitors possessed. The exact method in which all these changes are accomplished has been the object of the various theories referred to.

The accepted theory of cell origin, viz.—that cells are produced from pre-existing cells by division—is too familiar to the readers of this journal for it to be necessary to enter into any details concerning it; while the theory of aggregation advanced by Schleiden and Schwann having, with the exception of Dr. Bennett, of Edinburgh, few advocates among eminent physiologists, we need not stop to discuss it here.

The theory propounded by Wolf, as recently modified by Huxley, is briefly described :—

> "This theory supposes that the organism at the earliest period of its existence consists of a clear semi-fluid material. Soon certain changes occur in this; spaces or vacuoles which have the appearance of cells are formed. In these again, nuclei appear. The growth and multiplication of these spaces is effected by changes in the surrounding substance—by the surrounding material *growing* in towards its centre, and separating the vacuole, cell or space, into two parts." (p. 10.)

According to Beale, the chief difference between these two theories is that in the former the cell is the active part, while in the latter it is the *intercellular substance* which is active.

Beale says that in the organism it is certainly true that there are structures composed of bodies resembling cells; but contends that there are also tissues whose origin from mere cells it is not easy to make out.

> "In fibrous fasciæ, tendons, and ligaments, for example, we have a tissue containing here and there nuclei; but it is impossible to demonstrate in it at any period of its existence bodies which might be fairly termed cells. In the structures which apparently correspond to cells in some tissues, there is no cell-wall, hence they have been termed *nuclei*, while it is believed that the material, the fibrous tissue in which they lie, is formed altogether independently of these." (p. 10.)

So in the case of many other tissues; without enumerating any, however, he contends it is difficult to conceive how the cells were formed, and to explain how, by any changes occurring in the form of such cells, existing structures could be produced; and that while the formation of some tissues is therefore intelligibly explained, by the cell and other theories, there are others to which their application is exceedingly unsatisfactory, and entirely inadequate to account for existing appearances. While admitting this statement of Beale—especially in the application of the cellular theory to the so-called intercellular substances as illustrated by the hyaline intercellular substance of pure cartilage, to explain the formation of which, it is totally inadequate—it is but justice to Virchow to state that the modification of his views with regard to the essential character of the cell wall, *does* admit the application of his theory to the formation of a larger number of tissues.

The nature of this modification is given by a correspondent from Berlin to the *Edinburgh Med. Journal* for February, 1865, in which the writer states that " Virchow personally expressed to him that he *now did not regard a cell wall as an essential part of the cell* as given in cellular pathology; but that a nucleus surrounded by a molecular blastema was sufficient to constitute a cell; that the outer part of this cell blastema consolidates and forms a cell wall, as Beale has shown, and that this takes place in the amœba when thrown into fresh water." It will only be necessary for the reader to remember these statements when we come to develop the theory of Beale, to be convinced that the gap between the two theories is very much diminished by their admission.

The better to appreciate his own observations, and the train of reasoning based upon them, Dr. Beale asks us to dismiss, for the time being, all theories, and consider with him the changes actually seen to take place in the growth of various organisms, when examined under the most favourable circumstances, under the highest powers of the microscope.

Taking a little of a deposit of phosphate of lime as an example of inorganic matter, and placing it under the microscope, we find it presenting the appearance of a "number of minute granules possessing no form or structure whatever." Magnified by the highest powers you will indeed increase the size of the particles and bring others into view, but still there is no appearance of *structure.* Certain oscillatory *movements* are also observed among these particles, the so-called *molecular* movements first described by Mr. Robt. Brown. These particles being inorganic, the movements can be the result of physical forces alone.

Next he supposes a small fragment of dead animal or vegetable matter to be placed in a few drops of water on a glass slide and under the microscope. The water appears clear as the slide upon which it rests. Next place both these slides under the same conditions for a few hours, allowing free access of light and air. Then examining each again, the one containing the inorganic deposit of phosphate will be unchanged, except perhaps so far as an aggregation of some of the particles may have taken place. The second slide in which the organic material was mounted, before perfectly clear, now contains an additional number of minute granules, closely resembling those of the phosphate of lime, and manifesting similar molecular movements, suspended on either slide by the addition of a little gum, glycerine, or other viscid material, and recurring on dilution with water; indicating that in both cases these movements are due to physical causes.

Again, let both slides be set aside for a few hours, then re-examined, when we shall find the slide containing the inorganic matter still unchanged. But not so with the slide containing organic material. "The granules have increased considerably in number. Many have become altered, or their place is occupied by little bodies, some of which have a circular, others an elongated form, but all exhibit a remarkably simple structure." On the elapse of more time the change still continues. "The little bodies have become larger; in fact, they have grown, and have, moreover, considerably increased in number. It is easy to make out in the largest particles that *the central portion differs from the exterior*; in fact that each is composed of at least two substances, or a substance in two different states." Further examination of one of these will show these substances to consist externally of a delicate membrane, and within of a material having a granular appearance. These changes, it will be remembered, have taken place only in the organic or living particles placed under conditions favourable to the development of simple living organisms, and at a certain period the granules on the two slides could scarcely be distinguished, and they have been derived, not spontaneously, but from pre-existing living beings, in accordance with the law stated early in the lecture. And the compositions of these structural particles corresponds exactly with the compositions of the elementary parts of the higher animals. The external investment is the *formed material* of Beale; the granular material within is his *germinal matter.*

In further illustration of the structure of the simplest living organisms, Dr. Beale supposes the microscopic examination of a little ordinary mildew, the elementary parts of which are larger than those we have been examining. It will be observed to consist of a number of little round bodies, each having a *tolerably thick, well-defined outline*, while the *interior presents numerous small particles like dots*—the *two parts*, one externally, transparent, arranged to form an investing membrane, closed at all points, the other within, granular, and presenting no form. In these bodies, too, under favourable circumstances, certain changes will occur. Placed upon the moist surface of a glass slide and allowed to remain for a time, they first absorb moisture and swell up, and the membrane appears thinner than before, while the granules have increased in number. Second, "a new change is observed; at one point in the membrane a small orifice is formed, through which a little of the granular contents of the body covered with a thin layer of the inner part of the membrane passes, and thus a small nodule is formed which projects from the external surface of the membrane." This increasing in size gradually assumes a structure like that of the parent body; the membrane around it becomes thicker, and the attachment less, until complete separation takes place; when it becomes "an independent organism exactly resembling that from which it sprung, and capable of giving rise to new individuals like itself by a repetition of the process by which it was formed."

Other similar methods of multiplication of particles are admitted by Dr. Beale. In these an orifice forms on the membrane of the particle of mildew, and a little of the granular material escapes, but it does not separate as in the first case; it remains in connection with the mass, and grows out into a narrow thread-like process. The membrane on the external surface becomes thickened, and the whole increases in breadth. Within are contained a number of little spherical bodies or spores, like those observed within the circular body from which the process has grown. It may be that as this process grows, at one or more points a thinning occurs in its wall, and a portion of its contents coming into more immediate contact with the pabulum increases in amount, and thus gives rise to the production of another process or processes growing from and exactly similar to the first."

We have been thus particular in detailing the method of multiplication of living particles as given by Beale, because it is one of the points in which his theory differs somewhat, but not totally, from the "cellular theory" as held by Virchow. They evidently coincide as regards the source of the new body—always from a pre-existing organism; but while the cellular theory multiplies by duplication and reduplication of the original cell or elementary part, that of Beale makes the process more nearly allied to gemmiparous reproduction, by a budding from the original parent.

In both, the active agent is the whole or a part of the substance within the membranous investment, the cell contents and nucleus, according to the cellular theory, the *germinal matter* of Beale; while the membranous investment, the cell wall of Virchow, *formed material* of Beale, is passive. The *germinal* matter, descended from germs, is constantly producing germs. The *formed material*, inert, is formed from the germinal matter; hence the term applied by Beale.

It is the property of the germinal matter removed from any organism recently alive to be stained by an ammoniacal solution of carmine with glycerine, while the formed material is not thus stained; or if it be stained, owing to too great strength of the solution used, the stain is removed by soaking in glycerine, while the stain of germinal matter is rendered permanent by preservation in glycerine.

Thus a very convenient aid to study results from this property, without which it would be impossible, in every instance, to distinguish the matter which corresponds to the substance within from the external envelope of the mildew. "Every *elementary part*," which is the term Dr. Beale prefers to substitute for the ordinary word cell, "of every living organism may be considered to consist of matter in these two different states: *Germinal matter*, which, from inanimate nutrient material, will produce new germinal matter, and which becomes converted into *formed material;* and this latter substance which was once in the state of germinal matter."

The so-called *nuclei* and *nucleoli* of cells, which are stained of a deeper red by carmine than the surrounding germinal matter, Beale considers simply as new points of germinal matter, just converted from inanimate nutrient material, which passes in from without and becomes incorporated with the living granular substance by conversion into it. The new matter is not produced by deposition upon the external surface of the investing membrane, but is produced through the agency of the germinal matter in the interior. Were the former the case, the external membrane would become thicker and thicker as the growth advanced, while the central portion would remain unaltered; whereas, we find that as growth proceeds, the wall in most cases becomes considerably thinned.

The external membrane or formed material is in every instance the oldest portions of the elementary part, and the inner surface of the membrane is younger than the exterior. The formed matter of which the membrane covering the mass is composed was once granular germinal matter, and resembled that in the interior; but the particles composing it have passed through various stages of existence, and now no longer possess those wonderful properties which belonged to them at an early period of life—the power of communicating vital properties to inanimate matter. It is passive; dead.

The second lecture is devoted to further illustration of the theory and its application to the higher animal tissues.

> "The organism is made up of different tissues, and these tissues are composed of *elementary parts*. Each elementary part consists of *germinal matter* and *formed material*, which was once in the state of germinal matter and formed from it." (p. 26.)

The first application is made to *cuticle*, of which the oldest portions are known to be on the outside, and the most recently formed nearest the blood, the source of their nutriment. Microscopically, the different characters of different parts are readily noticed. That nearest the vessels consists of small masses of germinal matter closely approximated. Nearer the surface the masses have a more definite arrangement, each consisting of an oval body with an external membrane. Still nearer the surface the elementary particles appear more or less flattened, and a larger quantity of formed material (cell wall) is present, while at the surface the elementary parts present hardly any indications of germinal matter, and seem entirely composed of cuticular substance (formed material).

This is the history of the growth of cuticle according to our author:—

> "Here is a little mass of germinal matter, which grows and thus divides into two, each of these subdivide, and so on. Now each of these little bodies absorbs nutriment from the surrounding fluid. It increases in size. The older particles on its surface are altered and appear to be converted into a hard substance which is improperly described as membrane (cell wall). As it approaches the surface of the body the hard material becomes thicker and thicker, forming

the cuticular substance, until at length the germinal matter in the centre having nearly all undergone conversion into formed material, and being too far removed from the source of supply to increase at the same rate, the remainder perishes; by this time the elementary part in the form of the flattened scale of cuticle has reached the surface of the body, and is to be removed." (p. 28.)

Tendon, as the type of another class of tissues, is next selected for the application of the theory. Composed principally of so-called white fibrous tissue, under a power of two hundred diameters, a portion of fœtal tendon is seen to be made up of oval masses of germinal matter, with a certain proportion of intervening fibrous structure. Earlier in its existence it contained a larger proportion of germinal matter, and if its growth be watched, the fibrous material will be found to increase, while the germinal matter relatively diminishes, until in the adult tendon there is principally fibrous material, the germinal matter being present in very small quantity. This fibrous material is the formed matter which has undergone conversion from the germinal matter, which at this period is situated at regular intervals throughout the tissue, having the appearance of nuclei, and corresponding to the connective tissue corpuscles of the cellular theory. It is through these masses that the inanimate nutrient material is converted into fibrous matter. At the outer part of each is a layer of soft tissue in a transition state. It has ceased to be germinal matter, and is about to become tendon.

The application of the theory to the development of nerve fibre, as attempting to elucidate a subject of some obscurity, is interesting. The difficulty of the investigations is admitted, and it is only in the terminal distribution of the nerve fibres that the structure of the elementary part is to be made out. These fibres, as distributed to the elementary fibre of voluntary muscle, contain numerous oval masses of germinal matter, situated at short distances from each other, along the course of the fibre :—

"In an early stage of the growth of the fibre the masses of germinal matter are very close together, but as the growth of the fibre proceeds, the distance between the oval masses is increased. The germinal matter probably forms new tissue at either of its extremities, so that as the quantity of formed material is increased, the masses of germinal matter are farther and farther removed from each other. Hence, an elementary part of nerve fibre may be represented as an oval portion of germinal matter with an exceedingly delicate fibre projecting from each side of it." (p. 31.)

The third lecture is occupied principally with the consideration of the changes occurring in elementary parts, resulting from altered conditions of growth, and illustrated by the phenomena of the blister and formation of pus. To which are added some remarks on white blood-corpuscles and pus-corpuscles, and the process of secretion.

The lecture is opened by an apt illustration in a comparison of the process of crystallization, with the formation of living structures, according to the author's theory, which needs but to be referred to, to be appreciated at once. The two processes, instead of being similar are directly opposite, the former being the result of external deposition, while the latter occurs by internal deposit.

The changes occurring in elementary parts resulting from the change of the conditions under which they grow, are the causes of the different forms and properties of the various structures of the body, as well as of the changes which are the result of disease. The surface of the skin, for example, is perfectly smooth and even in health, because a balance of the two opposite processes of *removal* and *repair* is maintained. We have already seen that in cuticle there is a constant addition of new particles at its deep aspect, and these gradually pass towards the surface, increasing in size as they pass outwards, while the old particles on the outer surface are constantly being removed. So long as these two processes keep pace with each other, the normal condition of the skin is maintained. But suppose the skin, supplied with improper pabulum, or not supplied at all, a deviation from the balance results; old matter is removed from the surface, but nothing new may be produced to supply its place. Such a change occurs in scarlet fever:—

> "The morbid matter circulating in the blood interferes with production of new cuticle; for a time none is formed, but by and by when the violence of the disease abates, and the poison is in a great measure eliminated from the blood, the formative process is re-established. A gap, however, exists, as it were, between the tissue formed before the interference of the disease, and that produced after the natural process was resumed. In point of age they are separated by an interval, so that as the new cuticle grows up from below, the old is separated *en masse*. We may suppose that some change of this sort occurs in those creatures which, at regular periods, shed their skins." (p. 42.)

So the formation of tissues having peculiar properties depends upon the powers of the germinal matter. All tissues are formed from germinal matter, and though germinal matter presents everywhere the same appearance, it possesses different properties in different situations. Thus, the germinal matter of cartilage produces cartilage wherever placed, that of bone forms bone wherever transplanted; in illustration of which we have the well-known fact that though bone itself be entirely removed, if the germinal matter capable of producing it is allowed to remain, new bone will be produced. Hence the surgeon desires to leave the periosteum intact in the exsection of diseased bones, that new healthy bone may be produced. Certain morbid actions illustrate the same truth, one of which is the so-called "bone cancer." Certain minute particles, the germs of the growth, pass into the blood, and are carried by that fluid to different parts of the body; so minute, that they pass through the smallest lymphatics and capillaries; so great their vital properties, that when arrested in any part of the circulation and deposited in any tissue they take root, grow, and give rise to a structure resembling that from which they have been derived. So are maintained the peculiar properties of muscle, nerves and of secreting organs.

The process of secretion is illustrated by that of the liver. Though the ordinary diagramatic representations of the liver cell make it a well defined round or oval body, containing a nucleus, in reality no such regularly formed body exists, while some of the cells have a very irregular outline, often angular, and sometimes ragged. Nor can the constant existence of a cell-wall around the so-called liver-cell be demonstrated. Hence the cell-wall is not a necessary part of the cell, and Dr. Beale prefers to speak of it rather as an elementary part, consisting of a mass of formed material and germinal matter.

> "The germinal matter (nucleus) contains separate centres of growth, smaller masses of germinal matter (nucleoli) growing and appropriating to themselves new material, and capable of becoming a structure like the whole mass, so that all might be destroyed, except the nuclei and nucleoli, and these, retaining their vitality, would commence to grow anew." (p. 50.)

The mode of secretion of bile he thus explains:—

"The material from which the bile is to be formed transudes from the blood-

> vessels; it is absorbed into the interior of the mass constituting the 'liver-cell.' Here it is converted into the material of which the germinal matter is composed. The particles of this mass are constantly growing from centre to circumference, and when they have reached the circumference of the mass, having passed through various stages of existence, they become bile. So that in secretion the same rule is observed that we noticed in the growth of tissues. The conversion of new material begins at the centre, germinal matter is the form which it first assumes, and the particles of this substance towards the end of life give rise to particular tissues, or, in the process of secretion, to the peculiar substance which is resolved into the constituents of the secretion." (p. 50.)

I have been thus particular to give the author's precise words, that no misconception of his meaning can, if possible, arise. The easy applicabilities of this theory to other secretions, as the milk and urine, will, of course, be perceived.

According to Beale, the *white corpuscles* of the blood, *pus-corpuscles, corpuscles of the lymph and chyle*, and *the contents of the closed glands* are to be regarded as masses of germinal matter possessing the powers of growth. Hence their resemblance, though their powers are very different. The white corpuscles are prevented from undergoing any process of development into tissue by the constant motion to which they are subjected. If stationary from any cause, they give rise to the formation of a simple kind of fibrous tissue—"indeed, there is reason for believing that *fibrin is the formed material of the white blood corpuscles.*" So when lymphatic glands are enlarged and the quantity of fibrous tissue increased, Beale believes that the fibres in the substance of the gland are formed from lymph corpuscles. The peculiar tail-like appendages of many white corpuscles in the spleen, familiar to all microscopists, he believes to be the result of initiatory steps in the formation of fibrous tissue—they are formed material converted from germinal matter.

The formation of pus is illustrated by the phenomena of the blister. When an ordinary blister is applied, the skin swells, fluid is poured out beneath the surface of the cuticle, between the two layers, and the superficial layer is pushed up. If the deep surface of this layer be examined it will be found to consist of a number of elementary parts, each having a thick outer wall, with a central portion of germinal matter very distinct. In the subjacent fluid, too, a number of such particles will be found floating separately. If the irritation be kept up some time, we obtain, as is well known, a viscid fluid holding in solution a vast number of bodies composed almost entirely of germinal matter, and having a very thin investment of formed material, growing and multiplying rapidly. *These bodies are pus-corpuscles:—*

> "The effect of the irritation is such that the elementary parts of the cuticle are produced with greater rapidity than in the normal state. Nutritive material is supplied from the blood, and in greater abundance than usual, and this must be converted into living material. * *
> The nutritive material, then, is converted into germinal matter in the ordinary way, but so rapidly do subsequent changes occur that there is no time for the gradual production of cuticle. The elementary parts of cuticle are formed by a process of slow and gradual transformation of germinal matter as it grows old, into cuticular substance; but in the morbid state produced by the irritation of the blister, this gradual transformation cannot take place, and elementary parts consisting almost entirely of germinal matter, with very little formed material, are alone produced. Flakes of very soft spongy structure resembling cuticle are first formed, and these give place to the development of the substance we know as pus. In the process of healing, the order of the change is reversed.

The formation and multiplication of germinal matter gradually diminishes, and time is allowed for the proper cuticular material to be formed." (pp. 45–6.)

A sufficient number of examples have now been drawn from the different structures of the body to illustrate the formation of tissues from germinal matter, so that the remaining lectures, principally devoted to the development of individual tissues in detail, will be passed over in more rapid review. A few words only with regard to the *embryo*, which Beale considers as consisting "almost entirely of germinal matter, the separate masses of which divide and subdivide until the basis of each tissue is laid down. Then the oldest particles of the germinal matter of each mass become converted into the particular substance of which the tissue is to consist." We could wish this subject of the human ovum to have been more fully discussed. No reference is made to the germinal vesicle and spot of the egg, their origin, or the part they perform in the development of the embryo. The whole subject would be more complete had the egg been made the typical elementary part, if such it is considered, and the theory further illustrated by reference to it, as it is made the typical cell in the theory of Virchow.

The fourth lecture is occupied with a consideration of the ultimate microscopic constituents of tissues, with a view to a correct and uniform terminology which should be observed in writing and speaking of microscopic appearances, a matter of very great importance, as much misinterpretation of views has been the result of a careless use of terms. These are *granules* or *molecules, globules, fibres, perfectly clear, transparent, and structureless membrane, nuclei, nucleoli*, and *cells* or *elementary parts.*

The first is the *granule* or *molecule*, defined by Beale to be "a particle which is too small to exhibit any form or structure when examined by the highest magnifying powers we possess. It appears as a very minute *dot* or *point.*" Granules may be simple or compound, organic or inorganic, living or dead. *Living particles*, under favourable circumstances, *grow*, not by aggregation, but each individual particle increases in size by absorbing matter which surrounds it, and causing a complete alteration in the properties of this matter. Living granular matter can always be positively distinguished from inanimate granular matter by the ammoniacal solution of carmine, which stains the former, but leaves the latter uncoloured. The living particles tend to separate or divide, in obedience to a power resident in living matter which compels the particles to move in a direction *from the centre*, where the matter of which they are composed became living. The *inanimate granular* matter may be albuminous, fatty, or saline, albuminous being dissolved by acetic acid or alkali, fatty by ether, and saline by water, acids, or alkalies, according to the nature of the substance.

A *globule* is defined to be "a body which appears under the microscope circular, with a dark outline and transparent centre." They are generally spherical, but may be oval or irregular, and vary much in size. They, too, may be albuminous, fatty, or mineral, but the term is only properly applied to bodies of the above character of like composition throughout. The same tests indicate their composition. The thickness of the outline of a globule depends upon the difference between the refractive power of the matter of the globule itself and that of the medium in which it is immersed. The greater the difference the thicker the outline.

A *fibre* is defined as "anything which appears as a mere line, or solid and thread-like with a double outline." A fibre thick in the centre, and gradually tapering into thin lines at the two extremities, is called a "fibre-cell." Any tissue exhibiting lines parallel to each other, and exhibiting regularity, or arranged irregularly, crossing and interlacing in various directions, is said to exhibit a "fibrous appearance." This may be due to mode of formation, or produced artificially in some perfectly clear substances by the addition of chemical reagents.

Transparent membranes are not defined by Beale, most probably because the term membrane conveys to the minds of all moderately informed readers what it is intended to indicate. Yet there is an evident incompleteness in the paragraph, in consequence of the absence of definitions, whereas each of the other microscopic elements is defined. There is manifest difficulty in defining accurately a term so commonly used, and yet the various applications of the term would seem to call for a definition.

Examples of structureless membranes are often seen in the so-called "cell-wall," and the walls of capillary vessels. Appearances of a transparent membrane may also be produced artificially by the application of chemical reagents.

The remaining elements, *nuclei, nucleoli*, and *cells* or *elementary parts*, form definite masses which possess vital endowments, are therefore characteristic of living beings, and present a definite structure.

Our author defines a *cell* or *elementary part* to be "a structure always consisting of matter in two states—*forming* and *formed*, or *germinal matter* and *formed material*. The first or active substance is surrounded and protected by the outer passive matter, through which all pabulum to be converted into germinal matter must pass."

It will be remembered that the ordinary definition of a cell is that it is a perfectly closed sac having certain contents, among which is essentially a nucleus, but that, in accordance with the modified views of Virchow, who is looked upon as the exponent of the cellular theory, it does not materially differ from the cell or elementary part as defined by Beale.

"*Nuclei* and *nucleoli* are new centres which are developed in pre-existing living matter." Mere oil-globules should not be mistaken for nucleoli. Nuclei and nucleoli, as already stated, are always darkly coloured by carmine, while oil-globules do not receive the colour at all.

The fifth lecture is devoted to the anatomy and properties of *tissues*, of which Beale attempts no specific classification, because of the apparent impossibility of suggesting at present a classification which would assist the student. The usual classification—into, 1. Cell tissues; 2. Connective tissues; 3. Contractile tissues; 4. Nervous tissue—is given.

The so-called *soft connective tissue* is referred to as that soft silky fibrous structure serving as a connective medium between other tissues, and to support higher structures;—the *firm*, as illustrated by white fibrous tissue, and *hard connective* tissue, as seen in bone and dentine. Beale desires to show that the distinction commonly thought to exist in all these tissues, of *cells* and an intercellular substance, does not actually exist, and that the so-called "intercellular substance" has not an independent origin, but corresponds to "the wall" or "formed material" of an "epithelial cell." And here appears to us the strength of Beale's theory, contrasting favourably with the weak point of the cellular theory, so called; for it is in accounting for the intercellular substance of the connective tissues that the cellular theory is strikingly inadequate, while that of Beale explains most satisfactorily its presence.

The anatomy of tendon is first described, his specimens being made, not in the usual method, from desiccated tendon, but from moist tissue, thus obviating any changes which may be produced by drying and remoistening.

The relation of the formed material (white fibres) to the germinal matter (connective tissue corpuscles) was given in illustration of the theory in review of lecture I.

Beale considers the "canalicular system" of stellate cells and communicating tubes for conveyance of nutrient juices, as demonstrated by Virchow, to be dependent upon an alteration produced in the nuclei or masses of germinal matter, and upon the displacement and tearing of some of the young tissue connected with them; these the result of pressure and other necessary violence in making sections and other manipulations. "In the dead tissue they may be called tubes, but they are *artificial tubes*, and do not convey nutrient juices during the life of the tissue."

So with regard to the delicate fibres of yellow elastic tissue encircling the bundles of the white fibrous tissue of tendon, which Virchow considers tubular, and forming a part of this nutrient system, Beale has again and again failed to demonstrate any such tubular character.

It is well known that perfect white fibrous tissue is rendered transparent by acetic acid, and that yellow elastic tissue resists its action. Yet not all fibres which resist the action of acetic acid are yellow elastic tissue. The imperfectly formed fibrous tissue (nuclear fibres), or that portion of the formed material immediately joining the germinal matter, and which is not, therefore, perfectly-formed "formed material," also resists the action of acetic acid. This fact has caused observers to conclude that nuclear fibres are elastic tissue, which is erroneous. And it must be remembered that nuclei generally resist the action of acetic acid, and we use this reagent so much in anatomical investigations because it possesses the property of rendering fully formed tissue transparent, and thus the nucleus or germinal matter, and recently formed matter around it, become much more distinct.

Again, though white fibrous tissue, or all intercellular substance, is thus acted upon by acetic acid, it does not follow that this intercellular substance is produced in the same manner, possesses the same chemical or physical characters, and performs the same offices, in whatever organism or whatever part of an organism it may be found. True elastic tissue, such as is found in the ligamentum nuchæ, ligamenta subflava, chordæ vocales, &c., is always connected with and developed from nuclei; but there are many fibres ordinarily considered yellow elastic fibres, as the fine fibres encircling the bundles of fibrous tissue of tendon, and the nuclear fibres alluded to, which are not true elastic tissue. The first, according to Beale, are probably the remains of vessels or altered nerve-fibres, while the latter are recently produced formed material.

The *cornea* is treated of at this point as a modification of white fibrous tissue. Beale considers the so-called connective tissue corpuscles of the cornea, which are considered by Kölliker and Virchow cells for the distribution of nutrient material, simple masses of germinal matter, continuous with the fibrous tissue, and directly concerned in its formation.

The consideration of the fibrous tissues is continued in the sixth lecture. In the mucous tissue of the umbilical cord, where Virchow maintains the existence of special nutrient channels which anastomose with each other, and thus form a system of communicating tubes for the conveyance of nutrient materials, Beale fails to discover anything like such an arrangement. According to Beale, this mucous tissue of the umbilical cord

. . . "consists merely of a soft form of connective tissue, in which the fibres correspond exactly to the fibrous tissue of ordinary tendon. The interspaces between the finest of the fibres seem to be occupied with soft transparent granular matter.

"The fibres, with the numerous nuclei, are for the most part arranged to form the boundaries of more or less circular spaces. In the spaces are seen more delicate fibres, arranged without much regularity, and the nuclei are much less numerous in the central part of the space than they are amongst the fibres which bound it. As the tissue grows, the formation of new fibres takes place at the circumference. The nuclei of the older fibres die, and a great part of the fibrous matter itself is gradually softened and disintegrated; so that the circular spaces are gradually increasing in diameter as the tissue advances in age.

"An elementary part of this tissue consists of an oval mass of germinal matter, with ragged fibres projecting from either extremity, and often extending for some distance. Many of the elementary parts are triangular, and the fibres pass off in three directions. The fibres have the general appearance of ordinary connective tissue, and the germinal matter extends for some distance in opposite directions, gradually tapering into a very thin line, which is at length lost among the fibrous tissue. In the fresh tissues, therefore, there are no communicating tubes and lacunæ, as Virchow has described. What appears to be a space or cavity in the centre of the elementary part, is really occupied with germinal matter, and the apparent tubes contain prolongations from this imperfectly formed soft fibrous tissue. This soft germinal matter breaks down very soon after death, and thus spaces and tubes may result. These tubes do not exist as channels in the tissue during life, and the nutrient matter *permeates every part of the tissue, instead of flowing through any special channels.*" (pp. 91–2.)

We have thus quoted, almost entire, the remarks of Beale on this subject, because, as he remarks, Virchow regards this structure as one which especially favours his own view, and conclusions formed must necessarily influence our views upon the process of nutrition generally.

The *vitreous humour* is considered by Beale as a form of very delicate fibrous tissue, the fibres of which are combined with a very large quantity of water. Upon the inner surface of the hyaloid membrane, which is continuous with the vitreous humour, round masses of germinal matter exist, which are separated from each other by pretty regular intervals, and from them a very soft tissue can be traced into the vitreous, with which it is in fact continuous. To these so called cells the vitreous humour bears the relation of formed material to germinal matter in other situations.

According to this view, the oldest part of the vitreous humour is in the centre, while the circumferential parts are last formed, though Beale thinks it probable that this structure during life undergoes very slow changes indeed.

The seventh lecture is devoted to *adipose tissue* and *cartilage.*

Adipose tissue is generally associated with areolar tissue, and the fat vesicles lie in the spaces which exist in the areolar tissue. *Marrow* is a very pure form of adipose tissue.

The fat-cell, or vesicle, is the "elementary part" of adipose tissue. The fatty matter in adipose tissue is always situated within a very thin membrane, which is indeed a good example of a cell wall, though the young fat-cell has neither fat nor cell wall. The fat is formed and deposited in the substance of the granular material of which the fat-cell in its early stage is composed. The deposition of the fatty matter may be compared to the deposition of starch and some other deposits which Beale calls "secondary deposits," found after a certain period of growth, has been reached in some vegetable cells. But the fatty matter is not only deposited from a solution, but it is *formed*, and may be produced, though no fatty matter is taken with the food.

> "At an early period of development, we observe a number of oval or spherical masses of germinal matter (nuclei) in those positions where fat is to appear. These divide and subdivide as in the development of other tissues. The collection is freely supplied with capillary vessels. If the tissue be stained with carmine, each mass is coloured darkly in the central portion (nucleus), and external to this there is a layer of granular matter only faintly coloured. The latter gradually increases, and amongst the granules, a number of small oil-globules make their appearance, or only one is to be seen. * * The fat gradually increases, and soon occupies the greater part of the 'fat-cell,' which now consists of a large globule or several small globules of fatty matter, and a thin layer of granular matter around this, which is much thicker in one spot than elsewhere, and there the original nucleus is situated. The granular matter undergoes condensation at its outer part, and becomes the clear transparent cell-wall, or vesicle, and in the fully-formed fat-cell, the nucleus will be situated between the fat and the wall of the cell. As long as the nucleus or mass of germinal matter remains the fat may go on accumulating in the interior." (pp. 107–8.)

This fat Beale considers to be formed by a conversion of the granular or germinal matter of the elementary part. In this way also are produced the deposits of fat in liver-cells and the so called cartilage-cells.

With regard to cartilage, the greatest difference of opinion exists as to its essential structure and mode of formation. It is generally supposed that cartilage consists of *cells* and *intercellular substance*, and many contend that each cartilage cell possesses a very thin wall or capsule distinct from the cartilage matrix. By others, among whom is Virchow, it is considered that the soft granular matter just within the cell wall corresponds to the primordial utricle of plants. Beale contends that the cell wall cannot always be demonstrated as distinct from the matrix, which is sometimes absent, sometimes contains fibres resembling yellow elastic tissue, and in fibro-cartilage resembles white fibrous tissue. According to Beale, in the development of cartilages—

> "The masses of germinal matter at first are very close together; they divide and subdivide as they lie in the soft formed material, and, as development proceeds, become separated from each other by gradually increasing intervals. At the same time, the formed material undergoes slow condensation, and the formation of new material on the surface of each mass of germinal matter more than compensates for the shrinking of the matrix, which would otherwise be manifest. Each of these masses of germinal matter divides and subdivides, and formed material is produced on the outer surface of each, so that there are small collections of masses of germinal matter separated from each other by a considerable extent of formed material in the shape of fully-formed cartilage, while the separate masses composing each collection are themselves separated from each other by a very thin layer of recently produced and much softer formed material." (p. 113.)

According to our author, then, the matrix of cartilage is simply the formed material of the germinal matter constituting the so-called "cartilage cells," and corresponds with the cell wall or membranous capsule, of which the primordial utricle or inner membrane is only a younger portion.

This is evidently different from the teaching of Virchow, according to whom the membranous wall of the capsule *sends in septa* when the cells it contains undergo division, which serve as new envelopes for the young cells, yet in such a way that even the gigantic groups of cells which proceed from each of the original cells are still inclosed in the greatly enlarged parent capsules.

The eighth lecture is devoted to *bone*, which has been carefully investigated, but in which much still remains undetermined.

In bone the *formed material* is impregnated with calcareous matter, in such manner as to produce a very hard, unyielding tissue, which, however, possesses a certain amount of elasticity. The observations of most histologists are based upon the examination of *dried* bone, whereas they should be based upon the examination of *living* or *recently dead bone.* To this former method, Beale thinks may be attributed the difficulty of giving to the student a correct notion of the structure of bone and teeth. According to Beale—

> "An elementary part of *fully-formed* bone consists of a mass of germinal matter, surrounded on all sides by, and continuous with, a thin layer of soft formed material, which passes uninterruptedly into the hard calcified formed material (matrix or intercellular substance of authors). This hard material is penetrated everywhere by very fine channels (canaliculi) through which the nutrient material passes towards the masses of germinal matter. An elementary part of bone at *an early period* of formation consists of a mass of germinal matter, surrounded by a certain proportion of granular homogeneous or more or less fibrous formed material. This last becomes the seat of deposition of calcareous matter, which proceeds from *without inwards*, and the *formation of the canaliculi takes place in the same direction.* * * An elementary part of fully formed *dead* and *dried bone* 'consists of a space (lacuna) occupied in the recent state with germinal matter. Numerous pores or channels (canaliculi) pass from one lacuna to adjacent lacunæ.' In the dry bone lacunæ and canaliculi are both occupied with air, and in consequence of the great difference in refractive powers between the air and the bone tissue, the cavity and tubes appear black." (pp. 123–4.)

The *canaliculi*, according to Beale, are not processes of a cell, but *altered spaces* which are left between the calcareous globules originally deposited, and through them pass fluids to and from the germinal matter. The portion of the canaliculus first formed is that which is *most distant from* the lacuna and its contents.

> "No stellate corpuscle has been produced, but the stellate appearance results from the circumstances that the calcareous matter has been deposited in the matrix in such a manner as to leave intervals arranged in a more or less stellate manner." (p. 132.)

As to the contents of the canaliculi, in *dead dry* bone they contain nothing but air; in *young bone* they are filled with nutrient matter.

> "The bony tissue with its canaliculi and germinal matter, always has a certain definite relation to the vessels. It may exist as a simple thin lamina, covered upon each side with a highly vascular membrane, or as solid cylindrical processes often arranged so as to form a network, also invested with a vascular membrane; or the osseous tissue may be arranged in concentric laminæ around a central canal (Haversian canal), which in the living bone is occupied by a capillary vessel, around which are numerous *fine granular cells.* These cells are concerned in the removal of the osseous tissue. * * * * Of a thin plate of bone the tissue in the centre is the oldest. Of a solid cylinder, that in the centre was first formed, while of the laminæ of the Haversian system, those at the circumference are oldest, and the laminæ close to the central vessel were the last developed. The first two forms of bony tissue, constitute the cancellated structure, and the last (Haversian systems) make up the compact tissue of bone; but transitional forms exist." (pp. 133–4.)

The so-called *myeloid cells* are soft masses, having the appearance of large compound cells, composed of the elementary parts ("cells") of bone. At an early period of development, they consist only of several small oval masses of germinal matter, the outer part of which is undergoing conversion into formed material. This increases, becomes impregnated with calcareous matter, forms the little plates or cylindrical spiculæ of bone which enter into the formation of the cancelli. These myeloid cells are found beneath the periosteum as well as in the medullary cavity; and in disease, the soft spongy tissue which is formed in connection with the bone, consists of masses of this kind.

The *periosteum*, usually described as a fibrous membrane, in its outer layers exhibits a simply fibrous structure, but in its deeper portion are seen a number of elementary parts of unossified bony tissue, each consisting of an oval mass of germinal matter surrounded by a granular looking formed material. This deeper layer is the seat of the formation not only of new bone, but of complete Haversian systems.

The *medullary* membrane is a highly vascular membrane resembling periosteum, but more delicate and contains less fibrous tissue.

The medulla, or marrow of bone, is a form of adipose tissue existing in the cancelli, the medullary cavity, and even in the Haversian canals. They probably originate from the proper marrow cells (myeloid cells), which may become converted into bone tissue or marrow, some becoming the former and others the latter.

Development of Bone.—In mammalia, bone begins to form at an early period of intra-uterine life: 1st, by ossification of fibrous membrane; 2d, by ossification of temporary cartilage—most of the bones of vertebrata being represented in the first instance by cartilage.

The writer's view of the processes of *caries* and *necrosis*, processes important in a practical point of view, and yet imperfectly understood in so far as minute changes are involved, must absorb a moment's attention in this already too protracted review. In caries, as in the development of bone, the removal of old Haversian systems and the formation of new ones, in the union of fractured ends of bones and in the formation of bone cancer, "cells," or rather masses of germinal matter, are the active agents.

In *caries*, as in rickets, cancer, and ordinary suppuration, the vital changes going on are too active.

> "Increase is proceeding too fast, for the condensation of the tissue to take place. Here, as in all other cases, rapid change is associated with brief duration, while the well-developed normal lasting tissue is formed very slowly, and the changes succeed each other in the most gradual, orderly, and regular manner."
>
> "In caries, the germinal matter of a part of a bone receives too large a supply of nutrient matter, it grows too fast, and lives upon the surrounding tissue which has been already formed." (p. 145.)

In *necrosis*, the death of the germinal matter of many lacunæ takes place. "This results when the supply of blood from any cause is cut off." The passage of blood through the vessels being interfered with, the germinal matter of all that portion of bone receiving nutriment from them must die, and a piece of bone of a considerable size be "necrosed."

Beale explains the formation of the new bone around the sequestrum by supposing that around this the nutrient matter would flow more freely though less regularly; in consequence of which the germinal matter of the neighbouring lacunæ would grow much faster, and finally surround the dead bone. This, in turn, ossifies and the dead bone becomes surrounded by irregularly formed new bone. This Beale believes to take place, not in consequence of any irritation by the presence of dead bone, in consequence of which the cells are *excited* to *increased action*, but simply as the result of a more free access of nutrient matter. He says, "the so-called 'irritant,' instead of 'exciting,' acts in the most passive manner possible, it allows pabulum to have freer access to the living or germinal matter. It removes, to some extent, the restrictions under which growth normally takes place." (p. 147.)

The ninth lecture, which is a long one, is devoted to the *teeth*, the changes in which Dr. Beale thinks receive a most satisfactory explanation upon the new views propounded by him. Here, too, authors have committed the same errors as in regard to bone, by describing the anatomy of dead and dried tooth structure. The dental tissues, of all textures of the body, undergo the least amount of change.

The structures of human teeth are three: 1. Dentine or tooth bone; 2, enamel; 3, cementum or crusta petrosa. The second is the hardest, the first next, and the third the softest; though at an early period all were equally soft, the hardness being due to the deposition of calcareous salts.

The papilla existing, the dentine is formed upon the pulp, but not out of it, and grows constantly in one direction only, from without inwards, and therefore, when the extreme circumference is once formed, it is not possible that the tooth can increase in diameter by dentine, since dentine is never normally formed upon its outer surface. These processes continue, and the tooth gradually increases in depth by the formation of the fang which projects downwards towards the socket which is being formed for its reception. As already intimated, the dentine is not formed from the pulp, but from a *nucleated columnar* epithelium placed at right angles to the surface of the pulp. As new dentine is formed upon the peripheral portions of these cells, the latter encroach upon the pulp, the constituent tissues of which diminish in amount.

The so-called *dentinal tubes* of a *living tooth* are never empty; indeed, they are not tubes, nor are they canals for the transmission of nutrient substances dissolved in fluid, but they contain a soft solid substance, a portion of which near to the pulp is in a state of active vitality, and which is a prolongation from one of the columnar cells referred to. This corresponds with the *germinal matter* of Beale, while the wall of the tube, with the matter between the tubes corresponds to his *formed material*.

> "The elongated masses of germinal matter first of all produce *formed material*, which gradually increases as in other cases, upon the outer surfaces of the germinal matter. The formed material of the adjacent elementary parts is continuous, and calcareous matter is first deposited in the oldest part of this formed material. The calcareous matter appears in the form of globules, which gradually increase in size and often coalesce." (p. 156.)

The *enamel rods* are likewise formed from elongated cells which become calcified. These are situated entirely beneath a thin membrane to the under portion of which the most superficial portion or summit of these cells adheres. This membrane is highly vascular, and Dr. Beale has succeeded in making beautiful injections of it in the canine tooth of a pig three months old. The calcareous matter is first deposited in that part of the cell nearest the dentine which was first formed, and is deposited in small columnar masses in successive layers, which are indicated by transverse layers in the fully formed enamel rods The enamel cell increases in length, and the so-called nucleus moves away in a direction from the dentine as the increase takes place.

The *cementum* is not true osseous tissue. The lacunæ are often larger and more irregularly arranged, the matrix of the cementum is more transparent and harder, and much consists of a very clear transparent structure of a refractive power and hardness much resembling dentine, with small tubes traversing it here and there, but irregularly arranged. Again, the lacunæ are less numerous than in bone, the canaliculi are often of great length, and cementum is formed much more slowly than bone. Cementum is not formed by ossification of the tooth sac. It is continuous with dentine, and dentinal tubes may often be traced into its structure.

> "If the fang of an adult tooth, properly prepared, be examined, a very beautiful soft tissue will be found upon the surface. This takes part in the formation of the cementum, and is concerned in the formation of those exostoses which often grow upon the fangs of the teeth. It is composed entirely of what may be described as branching cells (elementary parts), the processes of which anastomose freely with each other. It is from this tissue that the crusta petrosa (cementum) is formed. It is a most perfect example of a tissue consisting entirely of cells, the cavities of which *communicate with each other by tubes.* The stellate cells are here as distinct as they are in the pith of the rush." (p. 164.)

But they do not, according to Beale, as according to Virchow, constitute an elaborate system of channels for the distribution of nutrient material to the tissue intervening between them. This tissue, growing very slowly, requires little nutrient matter, and the means are far more elaborate than would be expected..

According to Beale's view, these processes are not tubes in the living tooth. During life they contain a solid or semi-solid substance corresponding to that which occupies the so called dentinal tubes. It is *germinal matter* which is undergoing conversion into *formed material*, and the situations in which these so-called tubes existed are the last portions of the formed material to undergo calcification. Many of the stellate masses also disappear during calcification, while the number of processes or tubes projecting from those remaining is increased from ten or twelve to as many as thirty or forty. Hence Beale infers that these tubes are not an early stage of canaliculi, and the cells cannot become lacunæ simply by deposition of calcareous matter in the intervening matrix or intercellular substance. Still calcification takes place, and he also says, many processes become narrower and disappear, as do also many of the stellate masses themselves. This would seem to imply a diminution of the number of processes, which, as already stated, are increased, according to our author. This point is unexplained by him, and can only be accounted for by supposing that although some processes disappear, yet many others remain whose cells have disappeared, and thus the relative proportion of processes to lacunæ is increased. It must be admitted that there is a want of clearness in this section. In summary, Beale says, "the tooth is not developed from a papilla consisting of a sub-basement tissue, but it is formed in the very centre of a collection of cells, and it is clear that these cells have been formed in the central part of a pre-existing mass." According to Beale, enamel and dentine *are an epithelial structure* in the same sense that a hair or the cells in a glandular follicle are regarded as epithelial. This is in opposition to Huxley, according to whom they are *not epidermic* but *dermic.*

With regard to the so-called *membrana præformativa* or *basement membrane*, concerning which there is so much dispute, Beale contends that it is by no means constant, and considers it "*certain* that no præformativa membrane has been actually demonstrated *over* the enamel, as Huxley asserts, *between* the enamel and dentine, as many observers hold, or *beneath* the dentine." But supposing the basement membrane to be a necessary anatomical structure, he admits that the *proper position would be between the epidermis of the skin and the modified connective tissue of which the body* *of a cutaneous papilla is composed.* Yet he considers that such a membrane has no more to do with the *formation* of structure beneath it than the capsule of the seed with the formation of the seed itself.

The tenth lecture is on *life*, a part of his subject which our author considers himself incompetent to consider, but feels called upon to make some reference to the nature of life.

In the present course he has attempted to show that

> "All discussions with reference to vital actions must be restricted to the consideration of the changes which take place in the particles of germinal matter only, for here the inanimate matter certainly becomes living, and after retaining for a time the active power of animating new matter, the particles most distant from the centre where they become living lose all vital power, and become resolved into various substances, which, there can be no doubt, are again under the influence of physical and chemical laws." (p. 200.)

These changes Beale attributes to the influence of a peculiar power which may be called *vital power*, and feels compelled to accept an hypothesis, inconclusive though it be, until a reasonable explanation of the phenomena is afforded. We are enabled to investigate matter before it becomes living, and through organic chemistry we have learned much of chemical compounds produced when germinal matter becomes formed material, and when formed material is disintegrated. So we know something of the compounds resulting from sudden or slow death of germinal matter; but we *know nothing* of the relations existing between the different elements which constitute a particle of *living germinal matter.*

> "Between the time that the inanimate pabulum becomes living and the time that the living matter becomes formed material, there is an interval in which the matter exists in a very peculiar and exceptional state. *This is the living state—a state which is to be distinguished from every other state in which matter is known to exist*—a state not determined or caused by external circumstances, not capable of being communicated to matter through space, nor of being excited in matter by any known agents or combinations of circumstances—a state which may cease to be manifested at any moment, but which, as far as is known, cannot be caused to commence anew. Now, those who have discussed the nature of vital forces have not alluded to this temporary state. They have restricted themselves to the consideration of the matter before it assumed this living state, and after it had passed through it." (pp. 201–2.)

Beale thinks *living matter* of the different beings of creation always exhibits the same general characters, that the granules or spherules forming the germinal matter are made up of spherules ad infinitum—that the intervals between them are occupied by smaller ones separated from each other by fluid containing in solution, 1st, matter about to become living; 2d, substances not capable of being animated; and 3d, in many cases substances resulting from changes ensuing in particles arrived at the end of existence. He believes that all these spherules are free to move, and that the movements always take place in the same direction, *from* the centre at which the particles become living—*centrifugally.* These points of sphericity and centrifugal movement of the ultimate particles of germinal matter are much insisted upon throughout the lectures.

Our author admits that there is no evidence to show how these elements are related to each other, that the changes which occur cannot be explained by physical and chemical laws, and thinks it probable that the ordinary physical and chemical forces are in abeyance :—

> "It seems as if there existed at this time a power in obedience to which the

matter became affected in a manner we cannot explain. It is this power which we understand as the life. It is in obedience to this power that the living particles move *from* centres instead of gravitating *towards* centres, like the particles of ordinary matter." (p. 204.)

We fear that from this, as from other speculations upon the same subject, we obtain only inadequate ideas of the true nature of life, and as we are compelled to fall back upon an inscrutable Omnipotence as the source of life, so also we must be content to leave with such Omnipotence alone a knowledge of its true nature.

The remainder of the lecture is devoted to a brief consideration of *vital movements* as simply illustrated in contractility, the movements of the amœba, white blood cells, mucus-corpuscles, &c., as to the cause of which we can only say, *it is* LIFE; *to the chemical constitution of living matters*, of which we are ignorant, because chemical laws in this condition are in abeyance, and it is impossible to analyze matter in the living state; and to the *physical theory of life*. To this latter several pages are devoted. It is very properly denied that the formation of living tissue is the result of physical and chemical changes *alone*, that physical force is vital force. To convince the mind of this it is only necessary carefully to examine the phenomena of a single cell where vital actions are sufficiently distinct. But in these days there is little prospect of this—"the formation and destruction of faunas and floras, asteroids and worlds, suns, and systems, absorb the attention."

Beale objects to the employment, in speaking of lifeless bodies, of terms formerly exclusively applied to changes occurring in living things. Thus "the willow-leaf, like bodies in the photosphere of the sun at a temperature sufficient to convert many metals into vapor, are '*organisms*' which '*develop*' and '*elaborate*' heat and light from the bosom of a new luminous fluid (Sir J. F. W. Herschel, *Good Words*, 1863, p. 282)." So "Dr. Tyndall speaks of a watch as a '*little creature*' which shows 'signs of animation,' and is '*restored to life*' by the application of its key!" Such terms, he admits, are employed metaphorically, but they are open to much misconception.

At the same time, while denying the identity of vital and physical force, Dr. Beale admits that many of the phenomena now generally considered to make up the life of a fully formed organism, are physical phenomena, but contends "how very much there remains nevertheless to be explained!" The error of the physicist lies in this that he does not inquire how the matters decomposed were *produced*. Dr. Beale has been accused of materialistic views. We must confess there appears, in our conception, nothing in the little volume before us which can justify such accusation.

As has already been intimated, we fear that this review has been too prolonged. We have abstained from criticism, have quoted rather than commented, in consistency with our object early stated, to give to the American profession an opportunity of becoming familiar with the views of Professor Beale, of making such practical applications of them as possible, and of confirming or refuting them as may appear most consistent with the dictates of their own reason. J. T.